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AN AGE COMPARISON OF THE VESTIBULO-OCULAR COUNTERROLL REFLEX

Jay G. Pollack and Charles Diamond

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NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY
PENSACOLA, FLORIDA

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Naval Medical Research and Development Command
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SUMMARY PAGE

THE PROBLEM

The Bureau of Medicine and Surgery has been requested to develop age free criteria for flight classification of Navy and Marine Corps personnel. Within this context, the Naval Aerospace Medical Research Laboratory has undertaken a research effort to examine the integrity of the otolith system as a function of age. This report examines the relationship between age and a measure considered to be related to static otolith function, viz., the amplitude of ocular counterroll under conditions of static whole-body tilts.

FINDINGS

Ocular counterroll was measured using a photographic technique which took advantage of natural landmarks on the iris (11). Amount of counterroll was measured for left and right static whole-body tilts of 0, 17, 25, 37, 50, and 64 degrees. Two samples of subjects consisted of Aviation Officer Candidates (AOC) and Retired Naval Aviators (RNA).

When mean ocular counterroll was compared for the two groups, it was found that the RNAs had less counterroll than the AOCs. This difference was small and there was considerable overlap between the distribution of scores for the two groups. This result is in agreement with findings from histological studies on the senescent vestibular system, which indicates an age-related decrement in vestibular system integrity. It was also found that counterroll was more pronounced for head tilts to the right than to the left for both groups. This difference was of similar magnitude for each group and agrees with several previous reports (1,6,9). It was concluded that, because of the considerable variability in the responses from subject to subject, the potential contribution of the static counterroll response to the establishment of age-free biomedical standards is limited.

INTRODUCTION

Several lines of neuroanatomical study indicate that a wide range of degenerative changes that occur in the vestibular system, particularly the peripheral sensory structures, can be related to advancing age (4,7,13). In response to a request from the Bureau of Medicine and Surgery to develop age free medical criteria for flight classification this study was undertaken to determine if such age related changes could be discerned in the vestibular otolith system on the basis of objective measurements of the ocular counterroll reflex (OCR). The OCR is a compensatory ocular torsion in the direction opposite lateral head tilts which appears dependent upon the otolith system (2,11).

A reflex change in the OCR can be correlated with the direction and magnitude of linear acceleration, including gravity, acting upon man (14 15). Variation in perception of verticality, apparently dependent upon the presence or absence of otolith function (11) suggests relevance of this measure to spatial orientation in flight. For this reason, objective determination of otolith integrity, is a potential procedure for inclusion in age-free flight standards. Past technical development of measurement technique (10, 11) has contributed substantially to the study of otolith function by use of the OCR. The purpose of this study was to establish preliminary limits on the amplitude of OCR in young and old individuals.

PROCEDURE

SUBJECTS

The subjects for this study were divided into two groups on the basis of age. The first group (age range 22 to 34 years) consisted of 17 Aviation Officer Candidates (AOC) who volunteered to participate from the candidate pool and one Naval officer in a flight status. The second group of 17 Retired Naval Aviators (RNA), were volunteers from the population of Retired Officers Association members living in the Pensacola area whose ages ranged from 50 to 74 years. In addition, one retired Naval aviator, age 90, was studied, and his data are considered separately. The relative age distribution for the study sample is shown in Fig. 1. No attempt was made to preselect subjects on any criterion other than that they be sufficiently healthy to participate in the experiment without medical risk. All subjects were examined by an optometrist prior to undergoing testing and in all cases, vision was within normal limits for a given age. No major pathology, or history of vestibular disturbances was exhibited by any of the subjects. A summary of medical conditions present in both groups are shown in Fig. 2, some of which may effect the amplitude of the counterroll response.

METHOD

The apparatus and scoring technique has been fully described elsewhere (9, 11) and only a brief description is given here. The apparatus consisted of a standing litter, which could be rotated about the naso-occipital axis with a hydraulic power system. A bite bar and body belts maintained subject position within the litter. A 35mm camera equipped with a close-up lens assembly was secured to the litter so that it moved exactly with the head. Subjects' pupils were constricted by placing 1 drop of 1% pilocarpine in the left eye twenty minutes prior to the onset of data collection. Subjects were then placed in the standing litter positioned to 0 degrees (subject vertical). The right eye was covered with a patch, and though no attempt was made to remove all sources of light leaks, the experimental chamber was dark. Two photographs were then taken of the left eye in rapid sequence. The litter was then slowly rotated to the 17° position (right or left tilt counter-balanced across subjects) in about 10 seconds, and 2 photographs of the eye taken. This procedure was repeated for each right and left tilt of 17°, 25°, 37°, 50° and 64°. A final series of photos were taken again in the vertical 0° position. The return from the extreme right or left tilt position to zero was also performed slowly (about 15 seconds) and the subject remained in the 0° position for 1 minute before being tilted in the opposite direction. Scoring was performed by stroboscopically superimposing the test and control images and rotating the test image to obtain best alignment. Amount of counterroll was determined by taking the average of the two photos at each tilt position and comparing it to the mean of the vertical position photos. In all cases, the mean of the initial vertical position measurement was within 10 minutes of arc of the final vertical position data.

RESULTS

The overall results of this study are summarized in Appendix A. Mean counterroll for each group is shown in Fig. 3. Counterroll responses of the RNA group was less than the mean of the AOCs ($F\ (1, 32) = 4.866$, $p < .05$). The range of individual responses was well within that expected on the basis of earlier work; however, as with earlier studies, within group variability was high (absolute range 526 min/arc for the AOC group and 415 min/arc for the RNA group.

A previous study (1) indicated that a reduction in the amplitude of the OCR correlated well with advancing age. We examined our data for this relationship by performing point-biserial correlations between age groups and amplitude of counterroll response for each angle of tilt. These data are summarized in Table I. There was a weak, but statistically significant relationship between age and counterroll at the 3 smallest head tilts in the right ear down direction. At all other tilts no relationship was found. There was also no statistically significant correlation between age and the counterroll index (CI), where the CI is one half the sum of the maximum amplitude of counterroll to right and to left tilts. The relationship between amplitude of counterroll responses and age is further illustrated in Figures 4 and 5. Figure 4 shows a small but statistically significant decline of amplitude with age for 17 degrees right ear down tilt. Figure 5, at 64 degrees right ear down tilt does not exhibit a statistically consistent decline.

Table I

Point-biserial correlations for tilt angles and CI with age

POINT BISERIAL CORRELATIONS			
	DEGREES HEAD TILT	r	t VALUE
LEFT EAR DOWN	64	-.04	.27
	50	-.14	.80
	37	-.08	.46
	25	-.20	1.18
	17	-.19	1.13
RIGHT EAR DOWN	17	-.47	3.05*
	25	-.43	2.75*
	37	-.36	2.22*
	50	-.28	1.68
	64	-.12	.72
COUNTERROLL INDEX		-.16	.92

* $P \leq .05$

Figure 6 shows comparison of the data obtained in this study for both the AOC and RNA groups compared to data from a large sample of normals obtained previously by Miller (10). Miller's sample of 550 normals approximates a normal distribution of CIs with an arithmetic mean of 344 min/arc. Both the AOC and RNA group CI means were greater than that found by Miller; but were within 1SD of the mean, and therefore, not statistically different.

Previous studies (e.g., 1,6,8,9) have not been consistent in finding left-right differences in counterroll. Both groups in this study exhibited more counterroll (Fig. 3) for head tilts to the right than to the left (F (1,32) =13.8, $p < .001$). The amplitude of right tilt preponderance was similar for both groups. Of the total sample, 4 subjects, two RNAs and two AOCs, exhibited more counterroll to left tilts.

Two subjects were not included in the above analysis. The first, a subject in the AOC group, exhibited almost no counterroll response during the test. This is a highly atypical response for healthy normals. The subject, however, was not available for retest, and consequently it could not be determined whether this response was due to pathology. One subject from the RNA group was also not included in the analysis because of his extreme age relative to the remainder of the group. The OCR response in this 90 year old subject was much less than the mean value for the RNAs but greater than the lowest of these subjects. At a right head tilt of 64 degrees, this S exhibited 279 minutes of counterroll, and at 64 degrees of left tilt, he had 223 minutes of counterroll. The total range of 502 minutes was within 1 SD of the RNA group mean. By comparison, the smallest individual range for the AOC group was 454 minutes.

DISCUSSION

Sensitivity of the otolith system can be expected to occur with advancing age. In this study, statistically significant differences were found between two healthy groups of individuals with a mean age difference of 25 years. Our testing procedures differed from the "dynamic counterroll" method of Diamond et al. (1), but are consistent with their finding that a statistically significant correlation exists between age and counterroll amplitude. We were unable to replicate the high correlation found by Diamond et al. between age and counterroll, however. At three tilt angles there was a poor, but statistically significant relationship, but at other angles and using the CI, a relationship was not found. The subjects we tested tended to fall into two segmented groups, under 34 and over 60. In the Diamond et al. study, the ages were more evenly distributed, but the sample size was smaller than ours (8), suggesting that sampling may partially account for the difference in results. The difference in results may also be attributed to basic differences between the static and dynamic OCR measurement procedures used. Diamond et al. (3) has pointed out that over time, the dynamic method provides measurements which are considerably less variable than those obtained with the static procedure.

Our study showed less counterroll for equal head tilts to the left than to the right. This finding is in agreement with several earlier reports (1,6,9). This result may be attributable to the fact that we photographed only the left eye. If there is more counterroll to exocyclotorsion than to esocyclotorsions, this would appear in records from the left eye only as a directional preponderance to the right. Diamond et al., (1) recording binocularly, however, have shown a similar result ruling out the possibility that the OCR amplitude difference for equal left and right head tilts can be attributed to out-vs-in differences in cyclotorsion. In contrast to our results, Kellog (5) found the amount of counterroll to be equal for the two directions and studies by Linwong et al. (8) and Nelson and Cope (12) have found more counterroll to left tilts.

It is interesting to speculate on the comparison of our current data sample to that obtained by Miller (10). Miller (10) examined 550 assumedly normal adults using procedures similar to that described herein. His population mean, however, fell slightly below our RNA sample and still further below the AOC mean. It is possible that a constant unidentified bias was acting in one or both studies, but this does not seem likely. Indeed, the scoring procedure, one scorer and the experimental equipment were those used by Miller. The difference may be attributable to subject motivation and general health. In our study the entire ACC group were healthy males who had recently passed a Navy flight physical and all of the older subjects were in excellent health for their age and had normal optometric exams prior to testing. Both of our groups were highly motivated, unpaid volunteers, whereas Miller's were paid subjects from the general population and were not screened for physical defects. It is conceivable that the small differences found between the AOC and RNA groups in this study could be entirely attributed to the minor though general debilitation of health in the older subjects (see Figure 2). It is unlikely that the group wide decrease in counterroll was due to decreases in ocular motility since each subject was examined and found to have normal ability to move the eyes before testing, as indicated by standard opthalmic ocular motility tests.

One last point concerns the application of the static counterroll procedure to age free medical standards. An age-free medical standard is a statement of normalty for a physical condition or performance based task that is required for safe effective flying and which is not arbitrarily based on chronological age. This study did not explore the relevance of the OCR to flying, but assumed that an intact otolithic system would be necessary during some flight regimens. Further study on this point is required. Secondly, an age-free standard requires that normal limits be defined and be obtained repeatedly for any given subject or group of subjects. In this study, we found a wide range of "apparently normal" OCR amplitudes for both age groups. This finding is consistent with earlier reports (see Ref. 2 for review). Some of the variability can be attributed to differences in experimental techniques, but some may be attributable to the large individual differences observed in our study. It appears that the amplitude of the ocular counterroll reflex diminishes with age. With the static measurement technique used in this study, however, its potential contribution to the establishment of age-free medical standards remains problematic.

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APPENDIX A

Analysis of variance for a three-factor mixed analysis of variance design (repeated measures in two factors).

Factor A is young and old, B left and right tilt, C amplitude of tilt and S subjects.

TABLE A
ANOVA

SV	df	SS	MS	F	p
TOTAL	339	5959280.7			
Between S	33	2064715.3			
A	1	272529.0	272529.0	4.866	< .05
S/A	32	1792186.3	56005.8		
Within S	306	3894565.4			
B	1	567937.6	567937.6.	13.796	< .001
AB	1	54028.8	54028.8	1.31	NS
SB/A	32	1317314.8	41166.4		
C	4	75259.2	18814.7	11.82	< .001
AC	4	5770.3	1442.5	0.90	NS
SC/A	128	203597.8	1590.6		
BC	4	1352613.6	338153.4	142.60	< .001
ABC	4	14518.9	3629.7	1.53	NS
SBC/A	128	303524.0	2371.2		

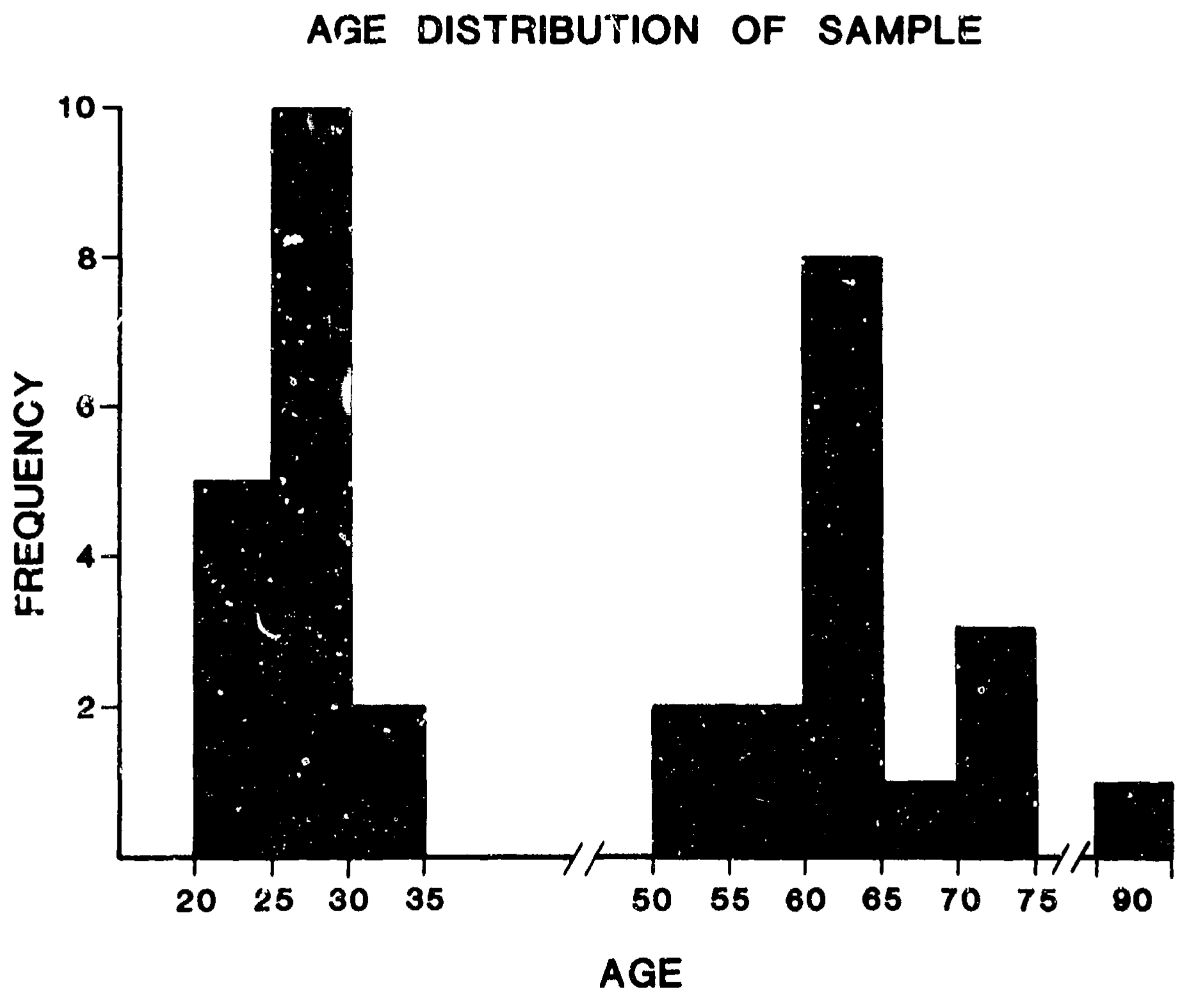

Figure 1

Distribution of subject ages for the two samples used in this study.

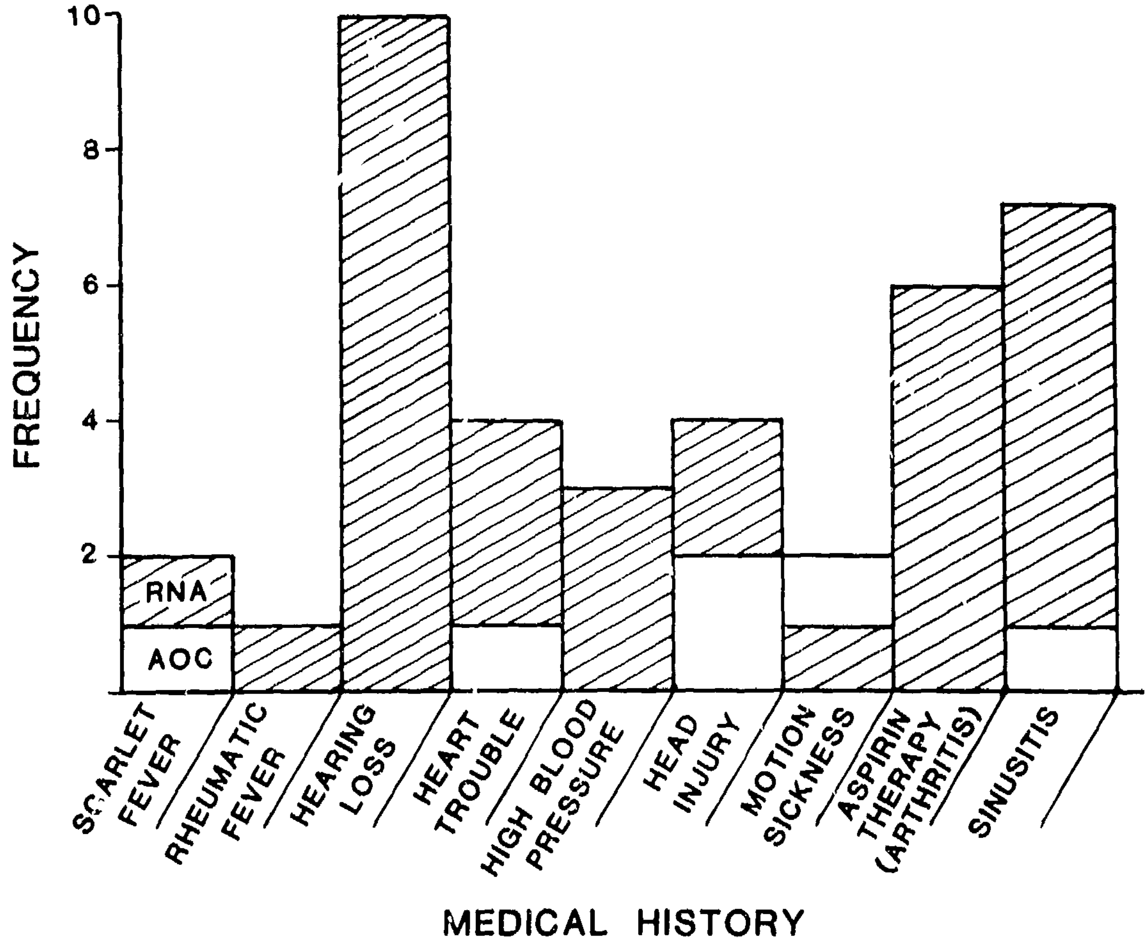

Figure 2

Comparison of medical conditions between the AOC and RNA groups as provided on USN Standard Form 88 of the Medical Department.

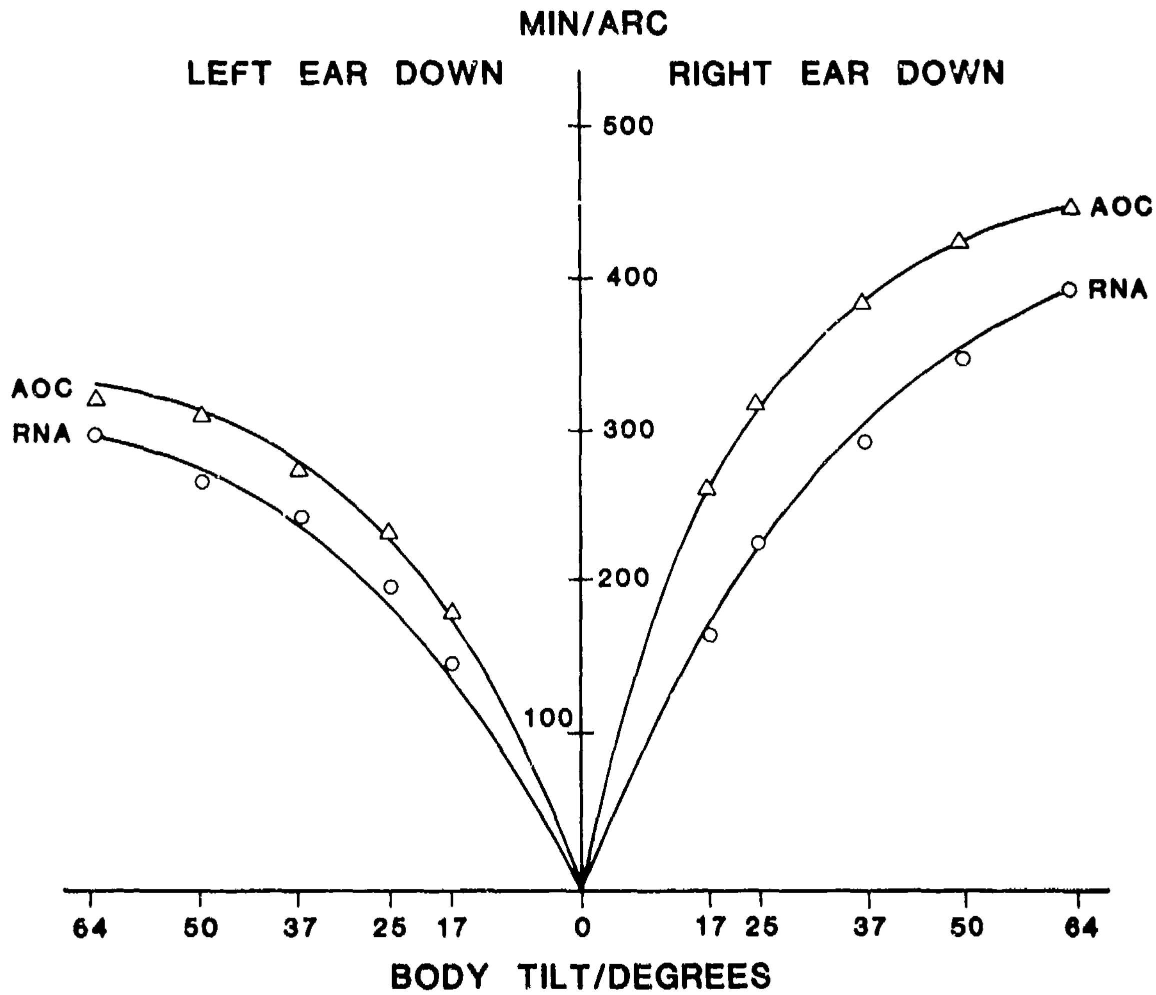

Figure 3

Mean counterroll in minutes of arc for each angle tested. Curves were fitted by hand to the data.

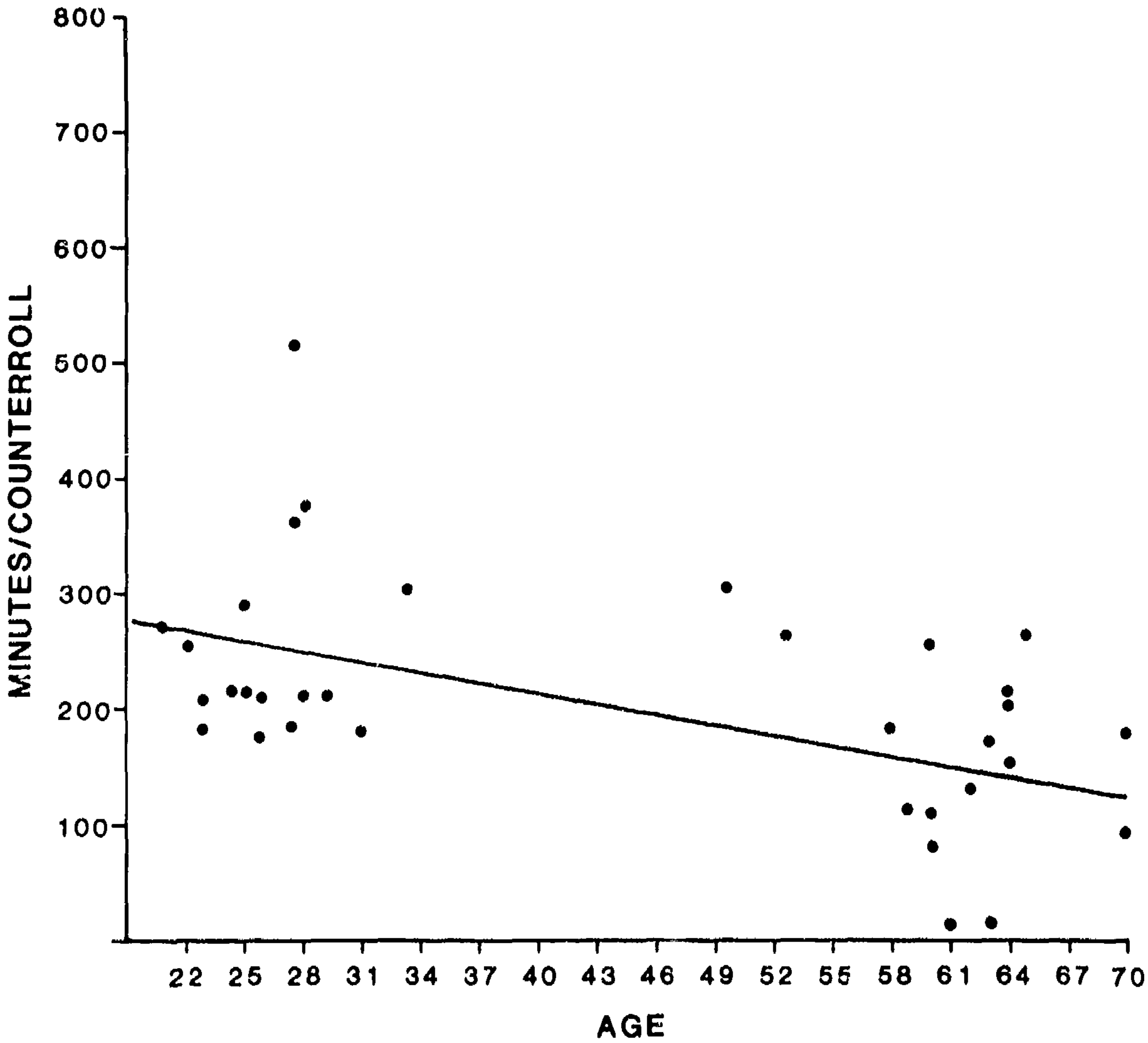

Figure 4

Regression line and raw data plotted for 17 degrees right ear down tilt as a function of age for all subjects. See text.

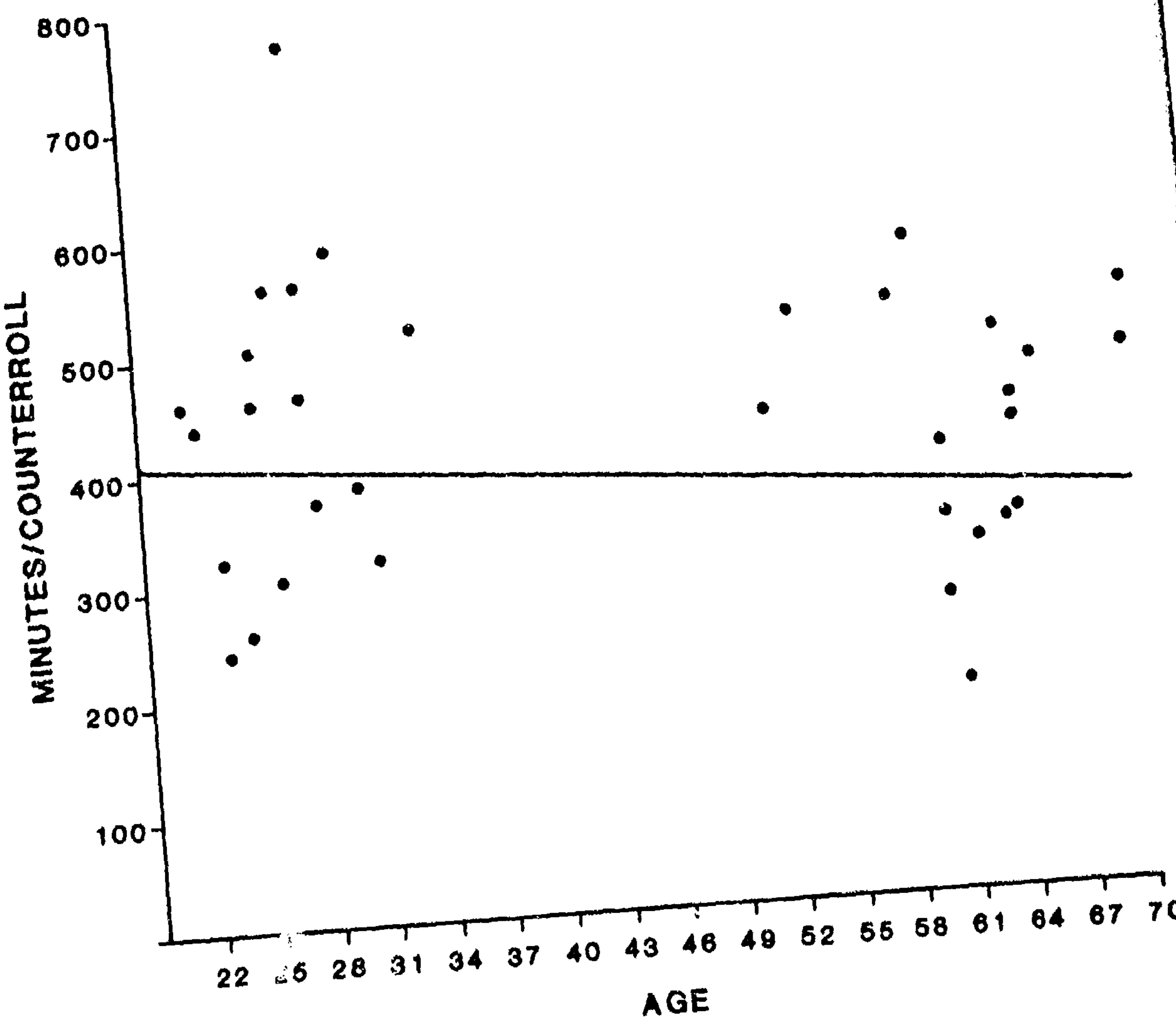

Figure 5

Regression line and raw data plotted for 64 degrees right ear down tilt as a function of age for all subjects. See text.

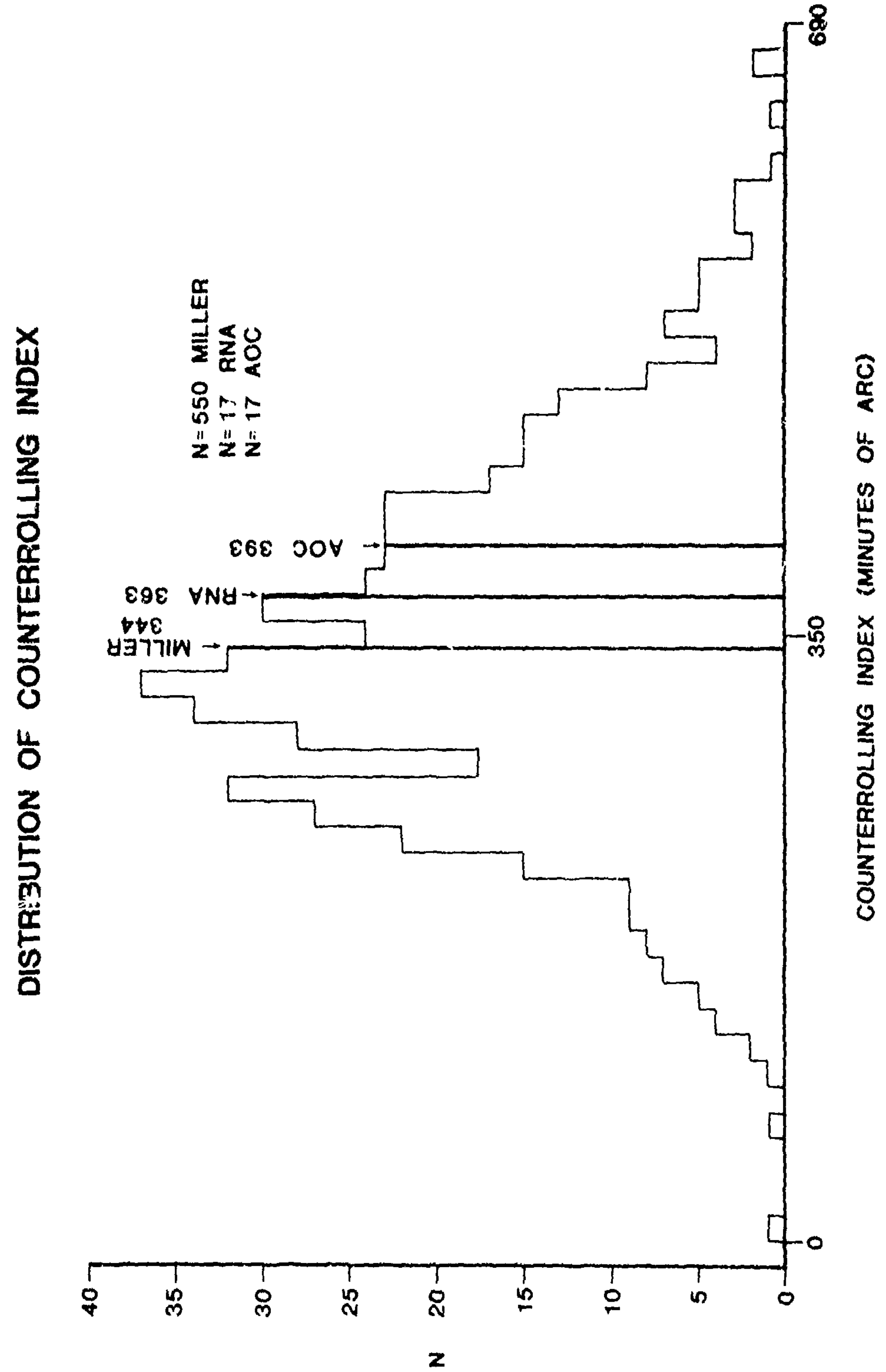

Figure 6

Comparison of the mean CI found for AOC and RNA groups with the normative data of Miller (10).

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